THE DETECTION OF LEAKS IN UNDERGROUND PIPES[1]

By H. E. Babbitt[2]

This subject is constantly before the average water works man and seldom fails to arouse interesting accounts of experiences in detecting leaks. In spite of the widespread experience of water works managers in this line the publications of the American Waterworks Association are strikingly barren of information concerning it. We must turn to water works periodicals, the publications of other associations, and to our personal experiences to find accounts of methods in use.

It is the aim of this paper to describe only a few of the more common methods for the location of leaks in underground pipes. It is not possible in the time available to discuss all the methods which have been used, nor is sufficient information at hand to do so. There are some here who will recognize all the methods described and be more familiar with them than the author is. Others will miss descriptions of methods familiar to them. To paraphrase the familiar saying attributed to Barnum: some of the methods described will be familiar to all of you, all the methods will be familiar to some of you, but it is hoped that all of the methods will not be familiar to all of you in order that some of you may receive something from this paper.

In order to reduce the extent to which this subject can be expanded, the ground covered will be restricted to methods for the exact location of leaks after their existence and their approximate location have been determined. The advantages to be gained by leak and waste surveys and methods for the determination of the existence of leaks and waste will not be included.

The simplest method for the location of leaks is by observation, if it can be called a method. It would scarcely seem to take much

[1] Read before the Illinois Section, March 25, 1920. Discussions are requested and should be sent to the Editor.

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experience to say "there is a leak" if water is seen bubbling up in a city street. Peculiarly the visual evidence may be sufficient to demonstrate the existence of a leak but its exact location may not be immediately below the point at which the water is appearing. However the thing to do is to dig at the point where the water is appearing, and if water is found coming in from the side of the hole, to follow along until the leak is reached or to use one of the more simple methods subsequently described. A water works superintendent who observes a luxuriant growth of vegetation along the line of his water pipes in the midst of a hot dry spell is safe in assuming that his pipes are leaking nearby and that an appreciable saving can be made by stopping the leak located there. If a sewer or drain pipe is seen to be discharging continuously even during the driest weather, suspicion should be directed to the line of water pipe that the drain crosses as contributing the flow through a leak.

Leaks discovered by observation in this fashion may follow along the pipes for some distance before making an appearance. If the leak is not located in the excavation made at the place of appearance, a pointed steel rod about $\frac{1}{2}$ to $\frac{3}{8}$ inch in diameter and 5 to 6 feet long can be driven down to the pipe through most soils. If on withdrawal the rod is found to be moist the indications are that the leak is further up-grade, and on withdrawing the rod in a dry condition the leak has been passed and lies between the last two points of driving the rod. Such a rod is called a sounding rod.

Sounding rods have no relation to the detection of leaks by sound, the most common manner by which they are located that is worthy of the name "method." The sound caused by the leak from a water pipe is a function of the velocity of flow, the size and condition of the opening, and whether the leak is discharging under water or into the air. A high velocity through a small aperture will make more noise than a large discharge through a large aperture. A free discharge will be more noisy than a submerged discharge. It is a well known law of physics that sound will travel faster and further through a solid body than through gas. If a leak is taking place in a pipe the sound will be transmitted by the pipe for long distances. The sound can be picked up by placing the ear against the pipe or some fixture connected thereto, or better by the assistance of some of the instruments made for the amplification of sound.

The aquaphone or waterphone is the simplest instrument and the most commonly used. The device consists of a solid metal rod

soldered to the center of a thin metal diaphram such as used in an ordinary telephone receiver. The point of the rod protrudes from the end of the receiver and is placed in contact with the pipe or fixture. The leak is located by following along the pipe as the sound increases. If the pipe is buried a sounding rod may be driven down to make contact with it. The aquaphone is placed in contact with the sounding rod. Considerable experience is necessary for the successful use of this instrument.

The detectaphone, the sonograph, the sonoscope, the geophone, etc., are somewhat similar instruments. The volume of sound in some of these instruments is increased by an electrical amplifier placed in line between the point of contact and the receiver. The receiver is similar to the ordinary telephone instrument with electrical coil and magnet. The sound waves set up in the pipe are converted to electrical waves, amplified and transmitted to the receiver, much more loudly and clearly.

It is to be noted that all of the instruments described so far require direct contact with the pipe. This may be a decidedly undesirable feature, as the exact location of a leak in a buried pipe requires excavations to be made in order to reach the pipe. The sounding rod does not always work well with the aquaphone.

Darley's Leak Locator is a sound detecting instrument that does not require direct contact with the pipe. A very delicate sound detector is set up on a four-legged brass table which rests on the surface of the ground, and is protected from air currents by placing the box containing the electric cells over it when in use. The vibrations set up in the detector are converted to electric waves which are transmitted through an amplifier to a very sensitive telephone receiver. The instrument is so sensitive that it will detect the sound of a leak through the pavement and the ground at the ordinary depths to which water pipes are buried. The instrument cannot be used in a high wind or where other noises may interfere. Satisfactory results have been obtained with its use.

The phenomenon of water hammer[3] is useful in locating a leak in a water pipe. It is well known that if a valve in a pipe line is closed quickly a pressure is set up in the pipe. This pressure is called "water hammer." It differs from the effect caused by a blow in that the

[3] See paper by Prof. M. L. Enger before Sixth Convention of the Illinois Water Supply Association.

pressure is maintained for some time. A wave of high pressure travels from the valve up the pipe to a point of relief and a wave of low pressure then returns to the starting point at the valve. The pressure at the valve fluctuates above and below normal until the disturbance has become stilled by the friction of its passage through the pipe, and the pressure returns to normal. Intermediate discharges between the valve and the point of relief will cause fluctuations in the pressure at the valve after the water hammer has been created, and if many of these intermediate discharges exist the fluctuations of pressure will be too confusing to be of value. The speed at which the wave travels is affected by the diameter of the pipe, its material, and other factors and varies between 3600 and 4200 feet per second.

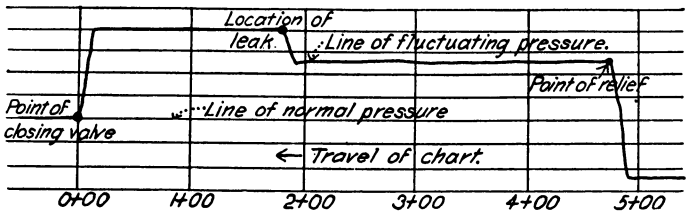

FIG. 1. TYPICAL WATER HAMMER DIAGRAM FOR THE LOCATION OF LEAKS IN PIPE LINES

In the application of this phenomenon to the location of a leak, the approximate location of the leak should be determined and the line of pipe on which the leak is located should be isolated by the closing of valves so that it is connected to only one large service main, preferably much larger than the pipe in question. It may be necessary to shut off service connections or to apply the method at night when the service pipes are not drawing water. A quick shutting valve is attached to a hydrant so located that the leak is between it and the water main. The distance from the hydrant to the connecting main along the pipe line should be measured accurately. A delicate recording pressure gage is attached to another nozzle on the same hydrant. Its dial is revolved by clock work. Time is recorded by the vibrations of a tuning fork. The instrument used by Professor Enger is an easily improvised affair and works quite satisfactorily. No time record need be maintained.

After the instruments are connected up and the clockwork is running, the valve is opened and water allowed to flow from the hydrant. The valve is then closed suddenly. On the closing of the valve the pressure line on the diagram, figure 1, made by the instrument will jump up. The pressure will remain at this height until a slightly relieving wave has returned from the point of the leak, when it will drop a little. The pressure will then remain constant until the low pressure wave has returned from the point of relief. The exact location of the leak is then determined by proportional distances from the diagram.

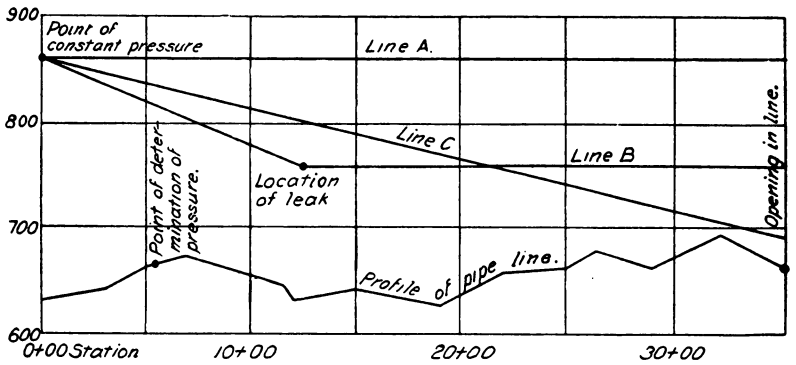

FIG. 2. TYPICAL DIAGRAM FOR THE LOCATION OF LEAKS IN PIPE LINES BY STUDY OF THE HYDRAULIC GRADIENT

The characteristics of the hydraulic gradient are useful in the location of a leak. Take the profile of a long pipe line, or a portion of a distribution system so isolated as to result in a similar condition, and assume that a leak exists somewhere between station 0 + 00 and 35 + 00, figure 2. If the pipe line is shut off completely except at 0 + 00 and no leak exists, the hydraulic gradient will lie along the line *A* and the pressure throughout the pipe line will indicate this height. If the pipe is opened and no leak exists the hydraulic gradient will be represented by the line *C* provided the diameter and other conditions are similar throughout the line. If a leak exists and the pipe is closed, the pressure at station 35 + 00 will be less than that at 0 + 00. The gradient will slope uniformly downwards from 0 + 00 to the point of the leak and then run horizontal to station 35 + 00 as shown by line *B*. The position of the gradient, represented by the two straight lines can be deter-

mined by locating any two points on each line. The leak will be found at the intersection of these lines as shown on the figure. This method was used with success by the author in locating a leak in a 5–mile pipe line at Nogent-en-Bassigny, France, during the war.

A method requiring the use of chemicals was suggested by T. J. Hoxie in the *Journal* of the New England Water Works Association, volume 27, page 307. The leak is located tentatively within a certain section of pipe which is then isolated as in the preceding method. It is essential that all service connections be closed. A corporation cock is tapped into the main somewhere above the leak. To this is connected a 6 or 8-inch length of 2 or 3-inch pipe and a valve. Two or three pounds of caustic soda are inserted in the tube, the large valve closed, and the time of opening the corporation cock noted. Samples are collected at various points along the line and tested for alkalinity with phenolphthalein. As soon as the alkalinity is found at any one point it indicates that there is a leak beyond that point because the flow created by the leak has carried the chemical down. Finally a point will be reached where the alkalinity does not appear. The indication is that the leak is somewhere between this point and the point at which it was last found. Water is withdrawn at the point at which the alkalinity has not appeared and the quantity withdrawn before the alkalinity does appear is carefully measured. This quantity, divided by the volume per unit length of the pipe will give the distance to the leak. Any number of leaks can be detected in this way.

An ingenious method based on volumetric displacement was used for the location of a leak in a pipe line during the construction of the Field Museum in Chicago. A piston was made which fitted the inside of the pipe. A Y-branch was inserted in the pipe line, the piston was put in the pipe through this branch, and a cable attached to the piston was passed through a packed joint in the plug closing the Y-branch. The water was then gently turned in the pipe just sufficiently to keep the piston moving. When it had reached the leak it stopped, and the length of the cable measured the distance to the leak.

A simple method for the location of a leak in a submerged pipe is to dump a quantity of bluing in the line. The appearance of the bluing in the river or harbor will locate the position of the leak. Other equally difficult methods may be as effective as the more scientific methods just described.

If the location of the pipe line itself is unknown there is an instrument available, known as the wireless pipe locator, by which the exact position of the pipe can be determined. An electric circuit is made by connecting two points on the pipe line by an electric wire. A battery and vibrator are put in this circuit, the vibrator serving to interrupt the current rapidly. An induction coil and a detecting coil connected to a telephone receiver are carried in the hand. When the induction coil held in a horizontal position is brought into the vibrating electric field set up by the electric circuit through the pipe and wire, a singing noise is heard in the telephone receiver. The volume of sound increases until the instrument is directly over the pipe, when it ceases altogether. If the coil is then turned into a vertical position the loudest sound is heard.

DISCUSSION

F. C. AMSBARY: Our company has located a number of leaks by observing pavements and parkings after a snow storm. The snow melts above the leak, leaving barren patches. Regarding the Darley leak finder, the company took advantage of the offer of the manufacturer to send one out on a 30 days trial, but failed to get any satisfactory results with it. The device is so sensitive that noises were picked up at great distances and the company's man gave it up. It is reported that the instrument has been successful when used at night.

The company has a pipe locator and it is a success; it has been in use for seven or eight years.

D. R. GWINN: At Terre Haute, the water company has a wireless pipe locator, an aquaphone, a detectaphone and a leak locator. The wireless locator and aquaphone have given very satisfactory service. The detectaphone has been valuable in locating underground leaks; by means of this instrument, it was possible to locate a serious underground leak on a service pipe. The other instrument, while very sensitive, has not been successful at Terre Haute, even on streets that were not paved.